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A zero crossing detector (9) including an analyser (13) adapted to determine a zero level crossing of a currently input electrical pulse packet and to output a trigger signal indicative of a determination having been made; and a pre-trigger unit (12) adapted to monitor variations in the amplitude of the currently input pulse packet to detect a crossing of a pre-trigger level. The detector (9) further comprises a control means (11) operably connected to the pre-trigger unit (12) and adapted to compare the amplitude of the pre-trigger level with an amplitude of a signal derived from one or other of the currently or a previously input electrical pulse packet and to automatically control the amplitude of the pre-trigger level provided to the pre-trigger unit (12) to maintain a working difference.

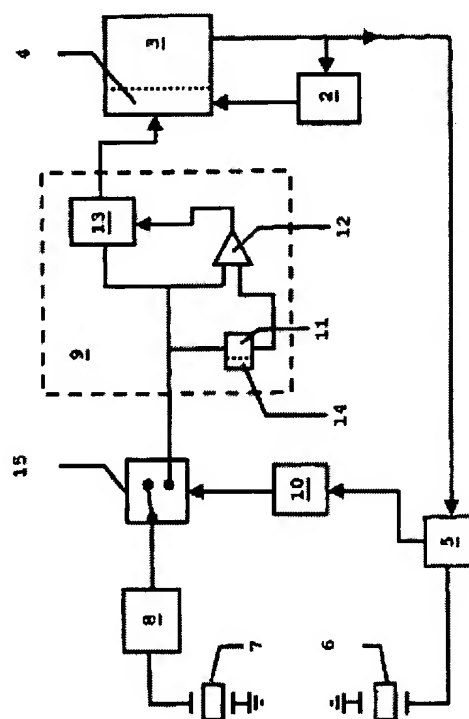


FIG. 2

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(54) Zero crossing detector and method of determining a zero crossing point

(57) A zero crossing detector (9) including an analyser (13) adapted to determine a zero level crossing of a currently input electrical pulse packet and to output a trigger signal indicative of a determination having been made; and a pre-trigger unit (12) adapted to monitor variations in the amplitude of the currently input pulse packet to detect a crossing of a pre-trigger level. The detector (9) further comprises a control means (11) operably connected to the pre-trigger unit (12) and adapted to compare the amplitude of the pre-trigger level with an amplitude of a signal derived from one or other of the currently or a previously input electrical pulse packet and to automatically control the amplitude of the pre-trigger level provided to the pre-trigger unit (12) to maintain a working difference.

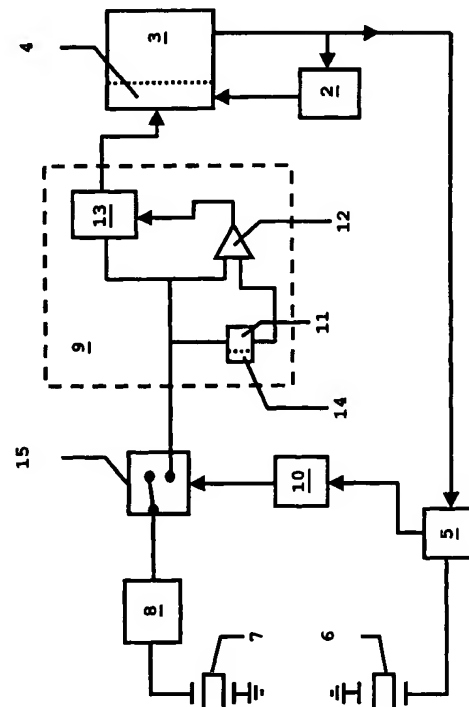


FIG. 2

Description

[0001] The present invention relates to a zero crossing detector and method for detecting the zero crossing of a particular pulse in a packet of individual pulses particularly pulses obtained from an ultrasound source.

[0002] It is well established that a piezoelectric crystal does not emit a single pulse when energised with a single electrical pulse. Rather the crystal is caused to oscillate at a characteristic resonant frequency to emit a "packet" that comprises a number of different amplitude pulses. The envelope of the emitted packet decays rapidly with time in a generally consistent manner, usually producing a train of six or so cycles. An ultrasound detector which receives the emitted packet will output an electrical pulse packet that generally mirrors the composition of the detected ultrasound packet.

[0003] Flow meters in which the transit time of an ultrasonic pulse between an ultrasound generator and an ultrasound receiver is used to determine the velocity (and hence the flow rate) of the fluid through which the pulse was transmitted are well known in the art. Devices, such as those described in WO 94/28790 and US 5,247,826, improve on this basic methodology by arranging for the transit times of ultrasonic pulses to be measured both upstream and downstream of the fluid flow. These transit times are then supplied to a micro-processor which is set to calculate the fluid flow rate using standard algorithms. However, as mentioned above, the received ultrasonic signal, typically transformed into a proportional electrical signal by the ultrasound receiver, will not comprise a single pulse but rather a packet of six or so pulses. Thus small errors in the determination of the flow rate may result if the determination is made using different pulses from within the packet.

[0004] It also is well known in the art to include a zero crossing detector in such a flow meter in order to detect the arrival of a pulse. This detector includes an analyser that operates by looking for a "zero" point crossing in which the amplitude of the detected ultrasonic signal, transformed to the proportional electrical signal, goes from "negative" to "positive" (or vice versa), crossing the zero point. Of course, it will be appreciated by those skilled in the art that the zero point need not be a true zero amplitude but rather a level approximately mid-range of an alternating amplitude signal.

[0005] When this zero point crossing is found the detector can then supply a trigger signal indicating that a crossing has been detected which may be used to trigger the halt of a timer. In this way known flow meters may generate a transit time of an ultrasonic pulse. However, as there will usually be several zero crossing points in any pulse packet a pre-trigger unit is often also provided within the detector which attempts to prevent all but the same pulse in each pulse packet initiating the trigger signal. The unit operates in combination with the analyser so that not until after the pulse packet signal has crossed a previously established threshold ampli-

tude (a so called "pre-trigger level") will a zero level crossing initiate the output of a trigger signal. This pre-trigger level is usually factory preset or set during an initial calibration of the meter before use in order to establish a "working difference" between the threshold amplitude and the anticipated amplitudes of the electrical pulse packet. As the pulses in the packet decay rapidly then all but the correct crossing can be discriminated against using this pre-trigger unit provided that the working difference is correctly set.

[0006] It will be appreciated by those skilled in the art from the subsequent description contained in the following pages that if the pre-trigger level is set too low it may be possible to register one of several crossing points of the electrical pulse packet as the necessary trigger and if set too high no crossing points may be registered. Establishing a working difference is therefore considered herein to involve arranging for the pre-trigger level to lie between these two extremes at an amplitude which will provide only a single zero-crossing point detection.

[0007] Unfortunately measurement errors may still occur even if the working difference was correctly set for one measurement as any changes in the absorption properties of the fluid through which the ultrasonic signal propagates; in the fluid flow rate; or in the operational characteristics of the ultrasonic generator or receiver with age; may mean the absolute amplitude of the proportional electrical signal pulse packet arriving at the pre-trigger unit could change to a level where it becomes possible to detect one of several crossing points or even no crossings at all.

[0008] Similarly, even when only a single pulse is generated within a pulse packet and that pulse is to be detected and registered using a zero crossing detector a pre-trigger level may still be used, for example to discriminate against noise or system fluctuations. Here again similar problems may occur if the working difference is incorrectly set.

[0009] It is an aim of the present invention to provide a zero crossing detector and a method for detecting a zero crossing within an input electrical pulse packet in which some of the problems associated with the setting of the working difference are mitigated.

[0010] This is achieved by the detector and the method according to the present invention, as defined in and characterised by Claims 1 and 9 respectively. By arranging for the automatic control of the amplitude of the pre-trigger level in a manner to maintain a correct working difference variations in the amplitude of the detected ultrasonic pulse packet which may have caused an improper zero-crossing point detection can be compensated for.

[0011] Usefully, the derived signal used by the control means in the comparison with the pre-trigger level is obtained from the currently input electrical pulse packet. This has the advantage that the detector is better able to respond to rapid changes in the amplitude between input signals.

[0012] However, a derived signal obtained from a previously input electric pulse packet may be advantageously used in some circumstances. This is particularly the case in circumstances where the use of the currently input electrical pulse packet would lead to unacceptable delays in the operation of the detector.

[0013] Preferably, the pre-trigger level is variable dependent on the maximum amplitude of the electrical pulse packet and is most preferably variable to maintain it at a constant fraction of that maximum amplitude. This makes use of the generally consistent amplitude relationship between pulses in a particular signal packet to more reliably establish a suitable pre-trigger level.

[0014] Such a detector as described above may be usefully incorporated into an ultrasonic flow meter of the type generally known in the art which operates by determining the time of flight of an ultrasound pulse between an ultrasound generator and receiver in a manner also generally known in the art.

[0015] An embodiment of a detector and flow meter according to the present invention and which operates according to the method of the present invention will now be described, by way of example only, with the aid of the drawings of the accompanying figures of which:

[0016] Figure 1 shows a typical electrical signal representative of an ultrasound wave packet emitted by a piezoelectric crystal.

[0017] Figure 2 shows a block diagram of the components of a flow meter according to the present invention.

[0018] Considering now Figure 1, this illustrates a typical electrical signal 1 generated as a result of the detection of an ultrasonic wave packet originating from a piezoelectric transducer when stimulated with a single electrical pulse and is representative of the amplitude variations of the detected ultrasonic pulses in that packet with time, t . As can be seen the electrical signal 1 comprises a number of rapidly decaying pulses with amplitudes which alternate about a "zero" level. In this example, a zero crossing detector that is configured to operate to detect when the signal 1 crosses the zero level, moving from "negative" to "positive", could possibly detect any one of the five crossing points P1..P5. As is known in the prior art a preset pre-trigger level V may be employed so that, in theory, only the crossing P3 triggers a correct detection. Figure 1 also illustrates what may happen in practice.

[0019] Assuming that the pre-trigger level, V , is set as shown. If the amplitude of the signal reduces as illustrated by the partial trace 1', for example because of a change in the properties of the medium through which the acoustic signal propagates, then the pre-trigger level will no longer be useable. Similarly if the pre-trigger level is set as shown by V' then a correct determination at P3 might still be expected in the above case. However, any increase in the signal, as illustrated by 1'', for example because of noise, may trigger an incorrect detection at the crossing P2. This would lead to an error in the determination of the arrival of the ultrasonic pulse when

using prior art flow meters that incorporate known zero crossing detectors.

[0020] A flow meter according to the present invention is shown schematically at Figure 2. A high frequency oscillator 2 is connected to a processor 3 which is in part configured to act as an elapsed time indicator 4. The indicator 4 operates in the present example to count the number of pulses generated by the high frequency oscillator 2 in a time interval defined by input start and stop signals. From a knowledge of the count number and the oscillator frequency the elapsed time may be calculated in a manner known from the prior art.

[0021] Also connected to the processor 3 is an electrical signal generator 5 which provides electrical pulses to a piezoelectric crystal 6 for generating an ultrasound signal. A second piezoelectric crystal 7 is physically displaced from the crystal 6 and operates to convert incident ultrasound pulses into electrical signals. An amplifier 8 is connected between the crystal 7 and a zero crossing detector 9, the output of which detector 9 is connected to the elapsed time indicator 4 of the processor 3. A time delay 10 is also provided in operable connection between the signal generator 5 and the zero crossing detector 9.

[0022] The zero crossing detector 9 comprises a control means 11, a comparator 12, an analyser 13 which operate as described below.

[0023] In use, the processor 3 produces a start command signal to the counter 4, the high frequency oscillator 2 and the electrical signal generator 5. On receipt of this start signal the counter 4 is primed to receive and count pulses input from the oscillator 2 which itself responds to the start signal by commencing the output of "clock" pulses at a known frequency to the counter 4. The start signal from the processor 3 also triggers the production of an electrical pulse from the generator 5.

[0024] The electrical pulse from the generator 5 energises the piezoelectric crystal 6 which then transmits a ultrasound pulse packet of the form generally shown in Figure 1 through a medium the flow of which is to be measured for receipt by the receiving crystal 7. This crystal 7 then converts the ultrasound signal to an electrical pulse packet of the same relative amplitude as the ultrasonic pulse packet. The electrical pulse packet passes through the amplifier 8 to serve as a currently input electrical pulse packet to the analyser 13, the comparator 12 and the control means 11.

[0025] The control means 11 detects the maximum amplitude of the currently input electrical pulse packet and stores a representation of that maximum amplitude in a memory 14 which representation substitutes an earlier stored representation. The substituted earlier stored representation of a maximum amplitude of a previously input electrical pulse packet is retrieved from the memory 14 of the control means 11 before its substitution and is compared within the control means 11 with a pre-trigger level. The control means 11 is further configured to control the amplitude of the pre-trigger level in de-

pendence of this comparison in order to maintain a working difference between the two thus compared amplitudes, for example by adjusting the pre-trigger level to remain a predetermined fraction of the earlier stored maximum amplitude that was retrieved from the memory 14.

[0026] The controlled pre-trigger level is then output from the control means 11 to an input of the comparator 12. The comparator 12 operates to compare the amplitudes of the pre-trigger level and the currently input electrical pulse packet to detect a crossing of the pre-trigger level by the pulse packet and to output a signal dependent on this detection. This output is used to control the operation of the analyser 13 to prevent a trigger signal being output from the analyser 13 until a crossing of the pre-trigger level is detected by the comparator 12. The analyser 13 is configured to determine a zero-point crossing of the currently input electrical pulse packet and to output a trigger signal when such a crossing is detected.

[0027] The trigger signal from analyser 13 passes to the elapsed time indicator 4 of the processor 3 where it acts to stop the indicator 4 counting. The processor 3 may be programmed to calculate the elapsed time using the count value from the indicator 4 and the known clock frequency of the high frequency oscillator 2 and from this to calculate the flow of the medium through which the ultrasound signal passed during transmission between the piezoelectric crystals 4, 5 in a manner known in the art.

[0028] In the present example the time delay 10 is operably connected with the zero crossing detector 9 and the signal generator 5 and functions to reduce any adverse effects of electrical interference on the operation of the detector 9. This may be achieved as shown in Figure 2. The amplified electrical pulse packet is passed from the amplifier 8 into the detector 9 via an automatic switch 15. The switch 15 is operably connected to the time delay 10 which closes the switch 15 at a predetermined time after transmission of the electrical pulse by the generator 5 so that substantially only the electrical pulse packet generated by the received acoustic wave can be passed to the zero crossing detector 9. It will be appreciated that the time delay 10 may be constructed in several ways and still realise its function.

[0029] It will also be appreciated by those skilled in the art that the electronic circuitry required to implement the described functions of the above described elements of the present invention can be readily and relatively easily realised using conventional engineering techniques.

Claims

1. A zero crossing detector (9) including an analyser (13) adapted to determine a zero level crossing of a currently input electrical pulse packet and to out-

put a trigger signal indicative of a determination having been made; and a pre-trigger unit (12) adapted to monitor variations in the amplitude of the currently input pulse packet to detect a crossing of a pre-trigger level; **characterised in that** the detector (9) further comprises a control means (11) operably connected to the pre-trigger unit (12) and adapted to compare the amplitude of the pre-trigger level with a derived signal representative of an amplitude of one or other of the currently or a previously input electrical pulse packet and to automatically control the amplitude of the pre-trigger level within the pre-trigger unit (12) to maintain a working difference therebetween.

2. A zero crossing detector as claimed in Claim 1 **characterised in that** the control means (11) is adapted to compare the derived signal representative of a maximum amplitude of one or other of the currently or the previously input electrical pulse packet.
3. A zero crossing detector as claimed in Claim 2 **characterised in that** the control means (11) is adapted to control the amplitude of the pre-trigger level to maintain it at a pre-determined fraction of the derived signal.
4. A zero crossing detector as claimed in any preceding claim **characterised in that** the pre-trigger unit (12) is operably connected to the analyser (13) to inhibit the output of the trigger signal until the crossing is detected.
5. A zero crossing detector as claimed in Claim 4 **characterised in that** the pre-trigger unit (12) is adapted to inhibit the input of the pulse packet to the analyser (13) to inhibit the output of the trigger signal.
6. An ultrasonic flow meter comprising a ultrasound pulse generator (5,6); an ultrasound receiver (7,8) adapted to output an electrical signal representative of an ultrasound pulse received from the generator (5,6); a zero crossing detector (9) adapted to output a trigger signal upon detection of a zero amplitude level crossing of the electrical signal; and an elapsed time indicator (2,3,4) operably connected to the detector (9) to receive the output trigger signal and adapted to determine the time elapsed between the generation of an ultrasound pulse and the output of the trigger signal **characterised in that** the zero crossing detector (9) consists of the detector as claimed in any preceding Claim.
7. A method of determining a zero crossing point of a currently input electrical pulse packet comprising the steps of:

establishing a pre-trigger level;

monitoring variations in the amplitude of the currently input electrical pulse packet with the pre-trigger level to determine when the amplitude of the pulse packet crosses the level; and 5

determining a first occurrence of a zero level crossing of the currently input electrical pulse packet after the signal crosses the pre-trigger level; 10

characterised in that

establishing a pre-trigger level comprises the steps of: 15

i) monitoring a derived signal representative of an amplitude of one or other of the currently input electrical pulse packet and a previously input pulse packet; and 20

ii) adjusting the pre-trigger level in dependence of the monitored signal.

8. A method as claimed in claim 7 **characterised in that** the derived signal comprises the maximum amplitude of one or other of the currently input pulse packet and the previously input electrical pulse packet; and in that adjusting the pre-trigger level comprises varying the level to below the maximum amplitude to maintain it at a predetermined fraction of thereof. 25 30

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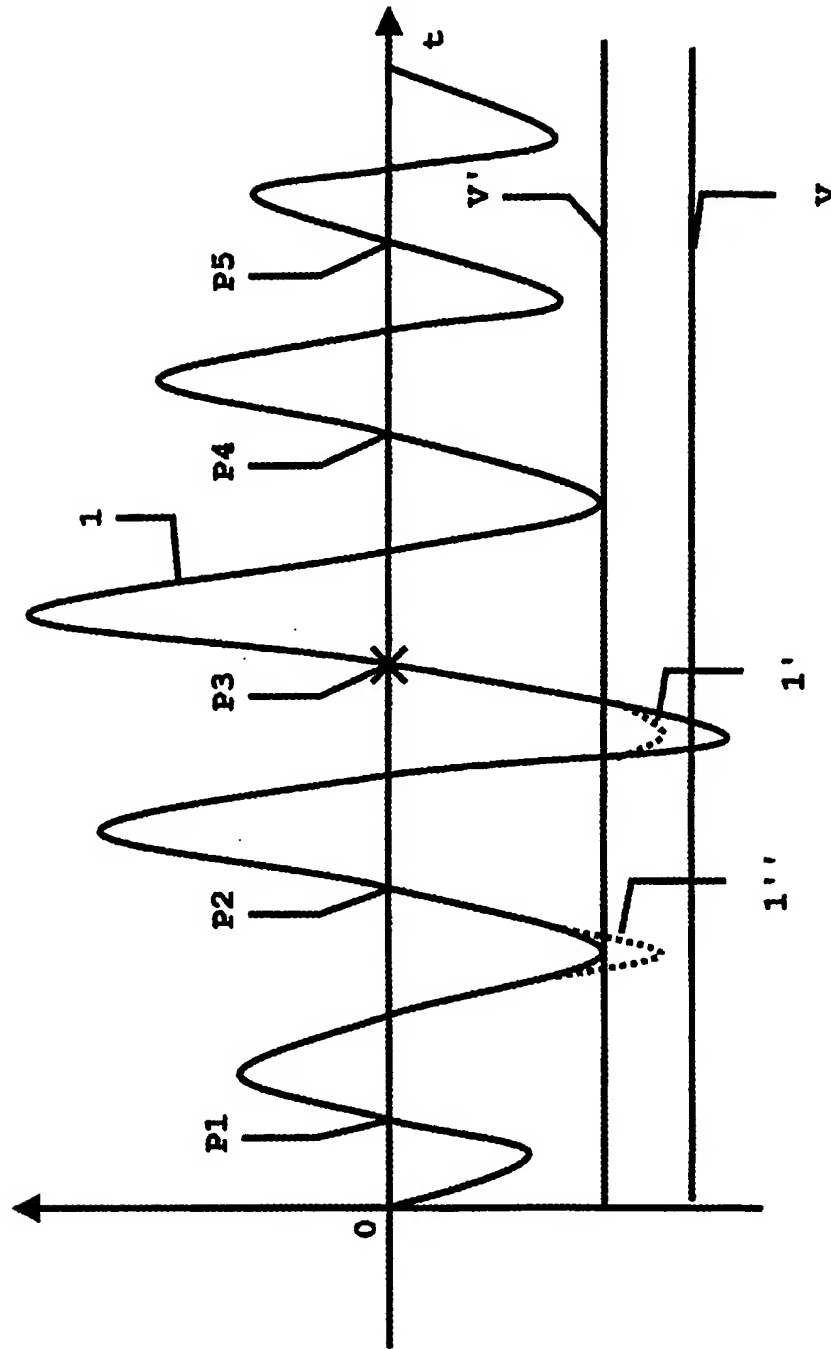


FIG. 1

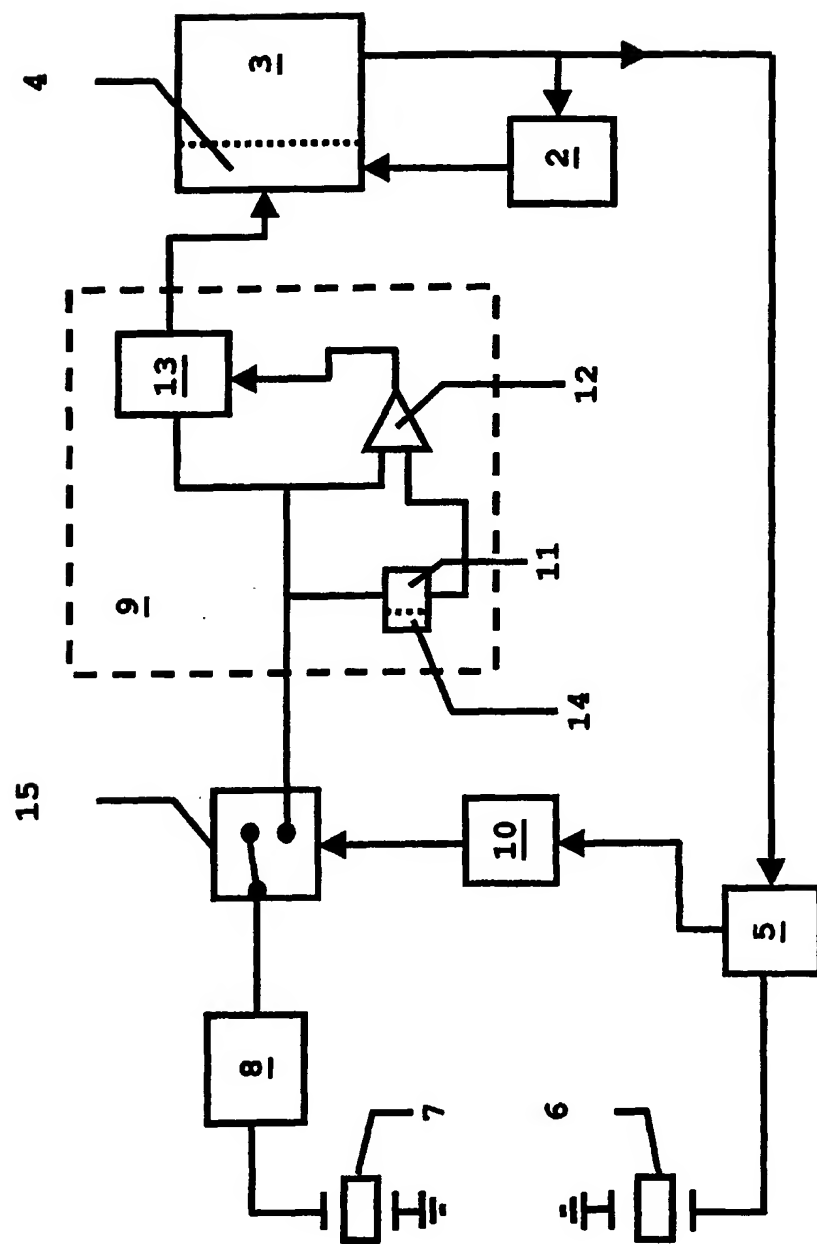


FIG. 2